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VERIFICATION OF MINIMUM TEMPERATURE "BIG CHANGE" EVENTS AT SALT LAKE CITY

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A study of forecast errors on minimum temperature forecasts involving big 24-hour changes was recently undertaken at the Salt Lake City forecast office. The study was prompted by the concern expressed by Western Region Headquarters over the regionwide poor performance on this type of event. Data covering both Salt Lake City and Cedar City were examined for the warm season (April-September) 1991. The standard definition of 10 degrees or greater change in either forecast or observed temperatures from the observed temperature for the period 24 hours prior was used to select big changes. It was hoped that factors could be identified which might help improve these forecasts.

The data were sorted by station, forecast period, and whether the change was to warmer or colder conditions. This was done in an attempt to isolate the primary factors contributing to each type of event at each location to see if there was any significant difference in results for the different forecast periods. Both an average error (BIAS) and the mean absolute error (MAE) were computed for each subset.

A number of interesting findings became apparent when analyzing the data. Most of these will be discussed separately for warm changes and cold changes below. However, one factor was present throughout the sample. The forecaster appeared to strongly favor the guidance from the LFM MOS equations over those from the NGM. Overall, the official forecast was closer to the LFM in 141 (72%) of the cases versus 56 (28%) for the NGM. It was unchanged from the LFM in 59 of the 141 cases (42%). This finding was ironic since the verification statistics indicated that the NGM provided the better MOS guidance in most cases.

Warm Changes

When the change was toward warmer temperatures, Cedar City presented the greatest challenge (largest errors) both for the forecaster and the guidance. This is the only case that bucked the trend of the NGM having the better guidance and for this situation its MAE was actually the worst in three of the four periods. The forecaster had the best MAE in the second and third periods, while the LFM won in the first and fourth.

The forecaster was usually much too cold with only 6 of the 52 forecasts having an error less than 5 degrees too cold. Only one forecast was too warm and that by only one degree. As can be seen in Table 1, the smallest BIAS was -6.0 degrees by the LFM in the first period and climbed to over -8.5 degrees by the fourth period for the NGM.

Table 2 shows that wind appeared to be the most consistent factor in these warm nights, showing up in 69 percent of the cases. It was the only factor identified in 5 of the 13 events. Clouds were also important in nearly half (46%) of the cases while air mass warming only seemed to play a part in 23 percent.

At Salt Lake City, the biggest difference noted was that the forecaster laid an almost exclusive claim to the worst forecasts (the LFM tied for this dubious honor in the third period) while the NGM had the best MAE in all but the first period. The favoritism of the LFM guidance was strong here with 67 percent of the forecasts closer to the LFM number and over half of these were unchanged.

The forecaster was even more consistently too cold. The only exception was a single forecast that ended up 1 degree too warm. However, the magnitude of the errors was not quite as bad with 12 of 52 cases having errors of less than 5 degrees.

In examining possible factors impacting these nights, wind and clouds were each identified in 69 percent of the events. In two-thirds of those events (or 49 percent of the cases), both were present. Air mass warming was present in 31 percent of this sample.

One note of interest on this point is that the wind as a factor was somewhat disguised at Salt Lake City. The surface winds were usually only a little (about 3 knots) stronger than the previous night as reported by the hourly observations. However, examination of the rawinsonde data revealed that in most of the cases attributed to wind, strong low-level winds were present on the warmer nights just above the surface inversion. This kept the lower levels of the atmosphere well mixed, limiting the nocturnal inversion to a much shallower than normal layer near the surface.

Cold Changes

This is where the NGM guidance was most consistently superior, ending up with a better MAE than the LFM in all forecast periods at both locations. Its average MAE for the four forecast periods was 1.56 degrees better than the LFM at Cedar City and 1.34 degrees better at Salt Lake City. The most dramatic improvement was in the second period when the NGM beat the LFM by nearly 2.7 degrees at both locations.

The NGM's MAE also beat the forecaster in all cases except the first period at Salt Lake City, and even there the forecaster was only marginally better (3.00 degrees versus 3.08). The NGM beat the forecaster by an average of 1.57 degrees at Cedar City but only by 0.57 degrees at Salt Lake City. However, in the second period the NGM beat the forecaster by more than 2 degrees at both locations.

The cold change cases at Cedar City were where the forecaster's bias toward the LFM was the most pronounced. A total of 73 percent of these forecasts favored the LFM. In contrast, the Salt Lake City cold cases had the smallest bias found in the study with only 54 percent of the LFM forecasts favored. This smaller bias toward the LFM is clearly reflected in the MAE's discussed in the previous paragraph.

The analysis of factors contributing to strong cooling is shown in Table 3. Air mass changes were much more important for the cold changes than for those with warming. Sixty-seven percent of the cases at Salt Lake City involved air mass cooling along with 63 percent of those at Cedar City. Wind (actually the lack of it) matched these percentages at both locations. The wind and air mass change appeared to combine in many of the cases (70% at Cedar City). Clouds were only identified as a factor in about one-third of the cases.

False Alarm Forecasts

A comparison of the number and nature of false alarm forecasts was also made. It was found that the NGM had a slightly higher number of false alarms than the LFM (11 verses nine for cold changes and nine verses seven for warming). The forecaster did somewhat better on this with only seven cold false alarms and two for warming. Almost all of these "erroneous" forecasts were for Cedar City with the exception of the NGM's forecasts of warming which were mostly for Salt Lake City. It should also be noted that for most of these events the actual temperature change was 8 or 9 degrees (only 13% less than 7 degrees) so the term "false alarm" may be a misnomer.

Conclusions

Attempting to draw conclusions from relatively small statistical samples always has some risk associated with it. Many of the findings about contributing factors do not come as a surprise to most forecasters familiar with these locations. However, two things seem to stand out in this study. One was the superiority of the NGM guidance on cold forecasts. This was also found to be the case in the cool season in another (unpublished) local study. At least for these two locations, **the forecaster should carefully consider the NGM guidance when significant cooling is expected.** It must be noted, however, that the NGM does overshoot the actual cooling in a significant number of cases (26% at Cedar City and 33% at Salt Lake City). But even those cases may offer good guidance as only a few overshoot by more than 3 degrees.

The other dramatic finding was the consistent, significant cold bias in cases with strong warming. Table 1 shows this was present throughout the samples with the best forecasts (LFM first period at Salt Lake City) still having a BIAS of over 4.5 degrees. Windy conditions were the most common factor identified in these cases with clouds also important. These conditions were usually associated with an approaching cold front. **Therefore, when the forecaster expects a windy night, especially along with cloud cover, it would seem wise to adjust the forecast upward from the guidance values (and the forecasters first guess).**

One final note of interest is that the majority of cases at Cedar City do not appear to be the result of the same forcing mechanism (the same trough or cold front) as those at Salt Lake City. One might have expected a vigorous cold front to cause strong cooling at both locations although possibly a day later at Cedar City. In reality, only 6 of the 16 cooling cases (38%) at Cedar City could be linked to an equivalent change at Salt Lake City, while only 15 percent of the warming cases appeared associated.

There are two additional cautions to be considered in trying to use these findings to improve forecasts. First, the findings should only be applied to expected big changes. Other local studies have indicated that on the smaller, day-to-day changes, the LFM has generally been better than the NGM. Adopting the NGM as the best predictor in all cases might significantly worsen the results for the majority of events. Second, new NGM MOS equations were derived after the end of this study period. Therefore, conclusions relating to the NGM should be used with caution until further studies can either confirm or refute these findings. However, those findings applicable to the LFM or forecaster as well as the factors contributing to big changes should be valid.

AVERAGE ERROR (BIAS) AND MEAN ABSOLUTE ERROR (MAE)
APRIL THROUGH SEPTEMBER 1991

24 HOUR MINIMUM TEMPERATURE CHANGES OF 10 DEGREES OR MORE WARMER

CEDAR CITY

FCST	FORECASTER		LFM		NGM	
PD	BIAS	MAE	BIAS	MAE	BIAS	MAE
1	-6.15	6.15	-6.00	6.00 *	-6.54	6.69 !
2	-6.38	6.38 *	-6.77	6.77	-7.31	7.46 !
3	-7.46	7.46 *	-8.00	8.00 !	-7.23	7.85
4	-8.08	8.23	-7.77	7.92 *	-8.62	8.77 !

SALT LAKE CITY

FCST	FORECASTER		LFM		NGM	
PD	BIAS	MAE	BIAS	MAE	BIAS	MAE
1	-5.69	5.69 !	-4.54	4.54 *	-4.85	4.85
2	-6.23	6.23 !	-5.77	6.08	-4.85	5.00 *
3	-6.54	6.54 !(tie)	-6.23	6.54 !(tie)	-5.15	5.31 *
4	-7.00	7.15 !	-6.15	6.62	-5.15	5.92 *

24 HOUR MINIMUM TEMPERATURE CHANGES OF 10 DEGREES OR MORE COLDER

CEDAR CITY

FCST	FORECASTER		LFM		NGM	
PD	BIAS	MAE	BIAS	MAE	BIAS	MAE
1	4.47	4.71 !	3.29	3.88	1.17	3.06 *
2	4.94	5.06	5.18	5.29 !	0.82	2.71 *
3	5.69	6.19 !	5.69	6.06	3.13	5.19 *
4	5.80	5.93	6.39	6.53 !	3.57	4.67 *

SALT LAKE CITY

FCST	FORECASTER		LFM		NGM	
PD	BIAS	MAE	BIAS	MAE	BIAS	MAE
1	1.17	3.00 *	2.42	3.92 !	-0.25	3.08
2	3.91	5.25	4.17	5.83 !	1.33	3.17 *
3	2.92	4.75	3.42	5.08 !	1.83	4.33 *
4	3.92	5.25	5.33	5.67 !	3.58	4.58 *

NOTE: * = best MAE ! = worst MAE

TABLE 1

METEOROLOGICAL FACTORS IDENTIFIED AS CONTRIBUTING TO 24 HOUR WARMING OF 10 DEGREES OR MORE IN MINIMUM TEMPERATURES

CEDAR CITY

DATE	LOW	FACTORS: AIR MASS	CLOUDS	WIND
APR 9 1991	37		X	X
APR 14 1991	38	X	X	X
APR 15 1991	48			X
APR 24 1991	47		X	X
APR 30 1991	37	X		
MAY 8 1991	59			X
MAY 16 1991	52			X
MAY 29 1991	57		X	X
JUN 28 1991	54		X	
AUG 17 1991	63	X		
AUG 30 1991	63		X	
SEP 9 1991	61			X
SEP 20 1991	57			X
TOTALS (PCT)		3 (23)	6 (46)	9 (69)

SALT LAKE CITY

DATE	LOW	FACTORS: AIR MASS	CLOUDS	WIND
APR 4 1991	52		X	
APR 14 1991	46	X		
MAY 5 1991	51	X	X	
MAY 16 1991	55		X	X
MAY 19 1991	48			X
JUN 6 1991	57		X	X
JUN 15 1991	64	X		X
JUN 18 1991	71		X	
JUL 7 1991	77		X	X
JUL 23 1991	69		X	X
AUG 5 1991	68			X
SEP 5 1991	70		X	X
SEP 13 1991	58	X	X	X
TOTALS (PCT)		4 (31)	9 (69)	9 (69)

TABLE 2

METEOROLOGICAL FACTORS IDENTIFIED AS CONTRIBUTING TO 24 HOUR COOLING OF 10 DEGREES OR MORE IN MINIMUM TEMPERATURES

CEDAR CITY

DATE	LOW	FACTORS:	AIR MASS	CLOUDS	WIND
APR 7 1991	26		X	X	X
APR 10 1991	13		X		X
APR 17 1991	28				X
APR 25 1991	29		X		X
MAY 9 1991	28		X		X
MAY 26 1991	44		X		X
MAY 30 1991	36		X		X
JUN 14 1991	49				X
JUN 19 1991	49		X	X	X
JUN 27 1991	36			X	
JUL 19 1991	52			X	
AUG 31 1991	53		X		
SEP 7 1991	47			X	
SEP 10 1991	49				X
SEP 14 1991	38		X		
SEP 21 1991	45		X		
TOTALS (PCT)			10 (63)	5 (31)	10 (63)

SALT LAKE CITY

DATE	LOW	FACTORS:	AIR MASS	CLOUDS	WIND
APR 6 1991	47		X		
APR 7 1991	30		X		
MAY 2 1991	39		X		
MAY 17 1991	39				X
JUN 5 1991	47			X	X
JUN 13 1991	59		X		X
JUN 14 1991	46			X	X
JUN 19 1991	54		X	X	X
JUL 8 1991	67				X
SEP 6 1991	60		X		
SEP 14 1991	42		X	X	X
SEP 21 1991	42		X		X
TOTALS (PCT)			8 (67)	4 (33)	8 (67)

TABLE 3